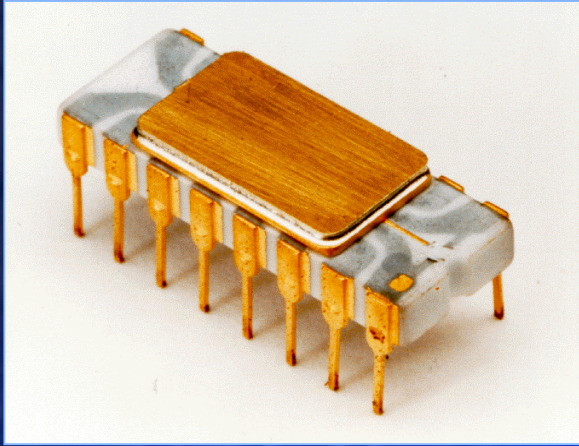


Advanced Cooling Strategies

Koushik Banerjee
Ravi Mahajan

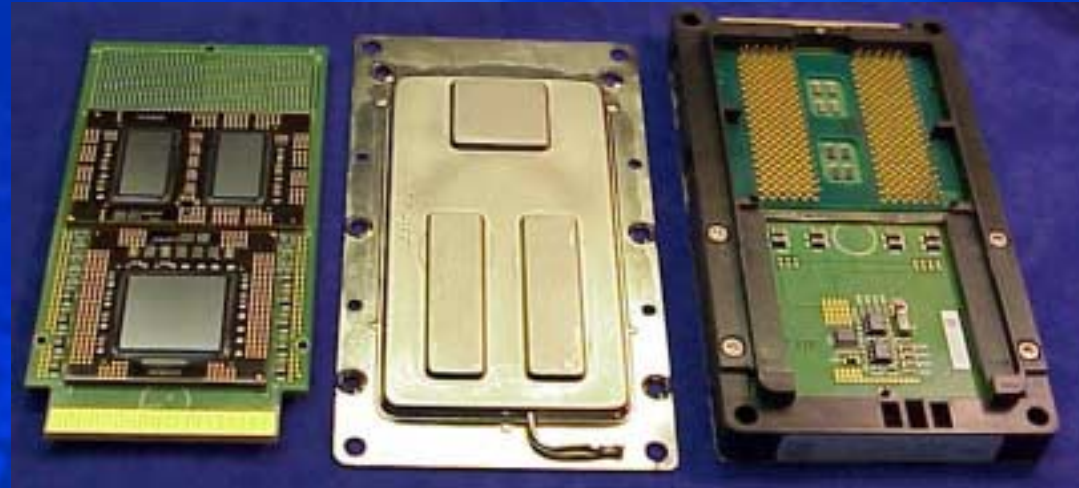
Assembly Technology Development
Intel Corporation

Microprocessors



1971

**What's a
Thermal Solution ?**



2002

**Very complex, integrated
Thermal Solutions**

Agenda

- Packaging research @ Intel
- Brief Backgrounder on thermals
- Specifics of the thermal management challenge
- Intel's current thermal management strategy
- Summary

Intel's Global Packaging Development



* Also Intel Assembly and Test Site

Main R&D facility in Chandler, AZ

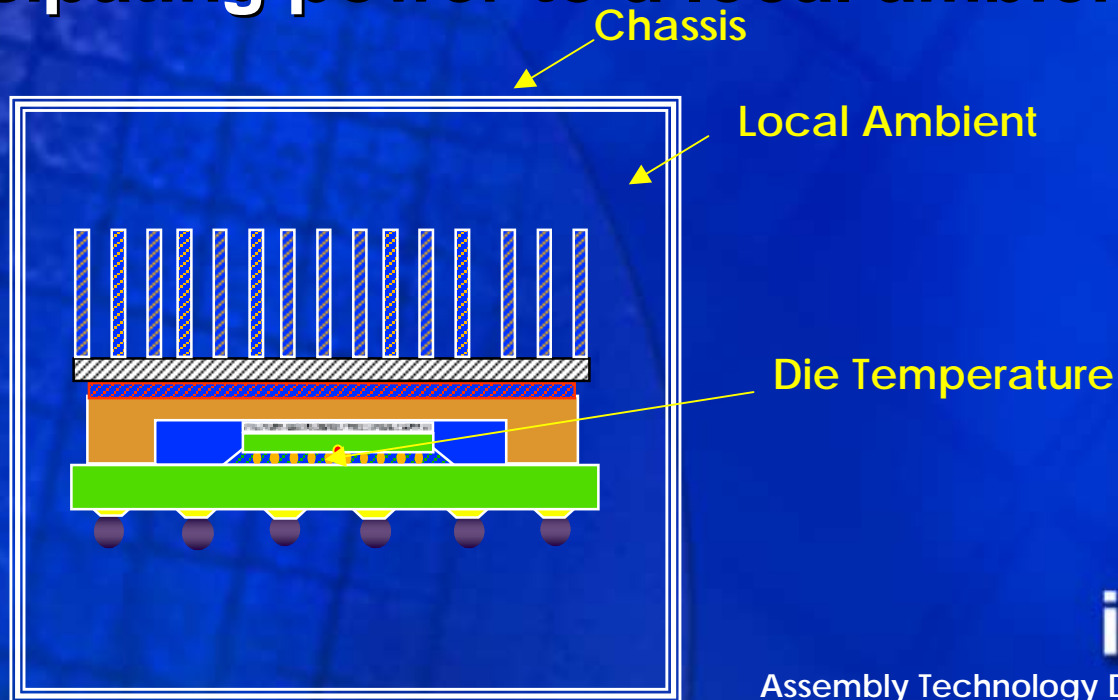


Agenda

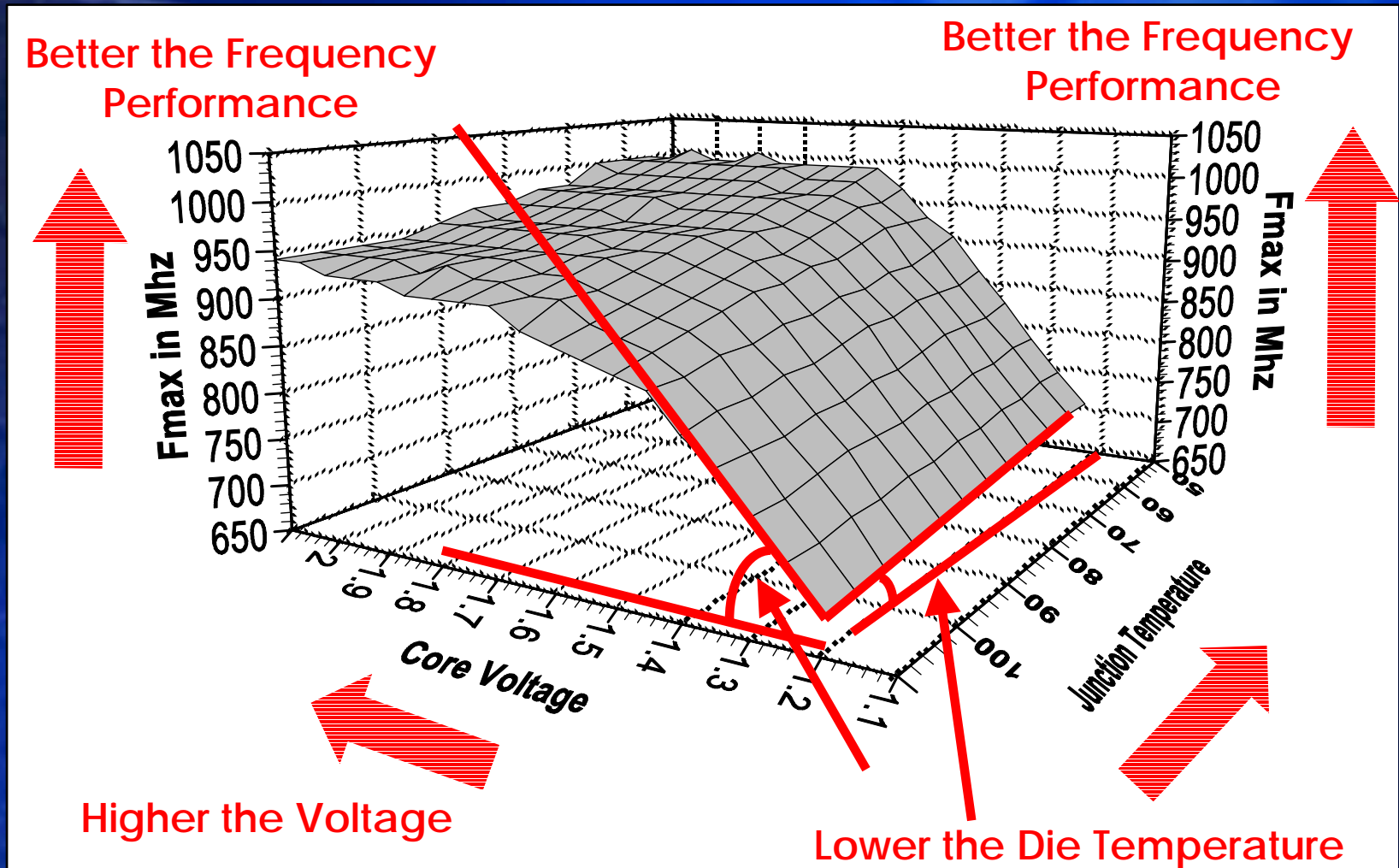
- Packaging research @ Intel
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Thermal management objective

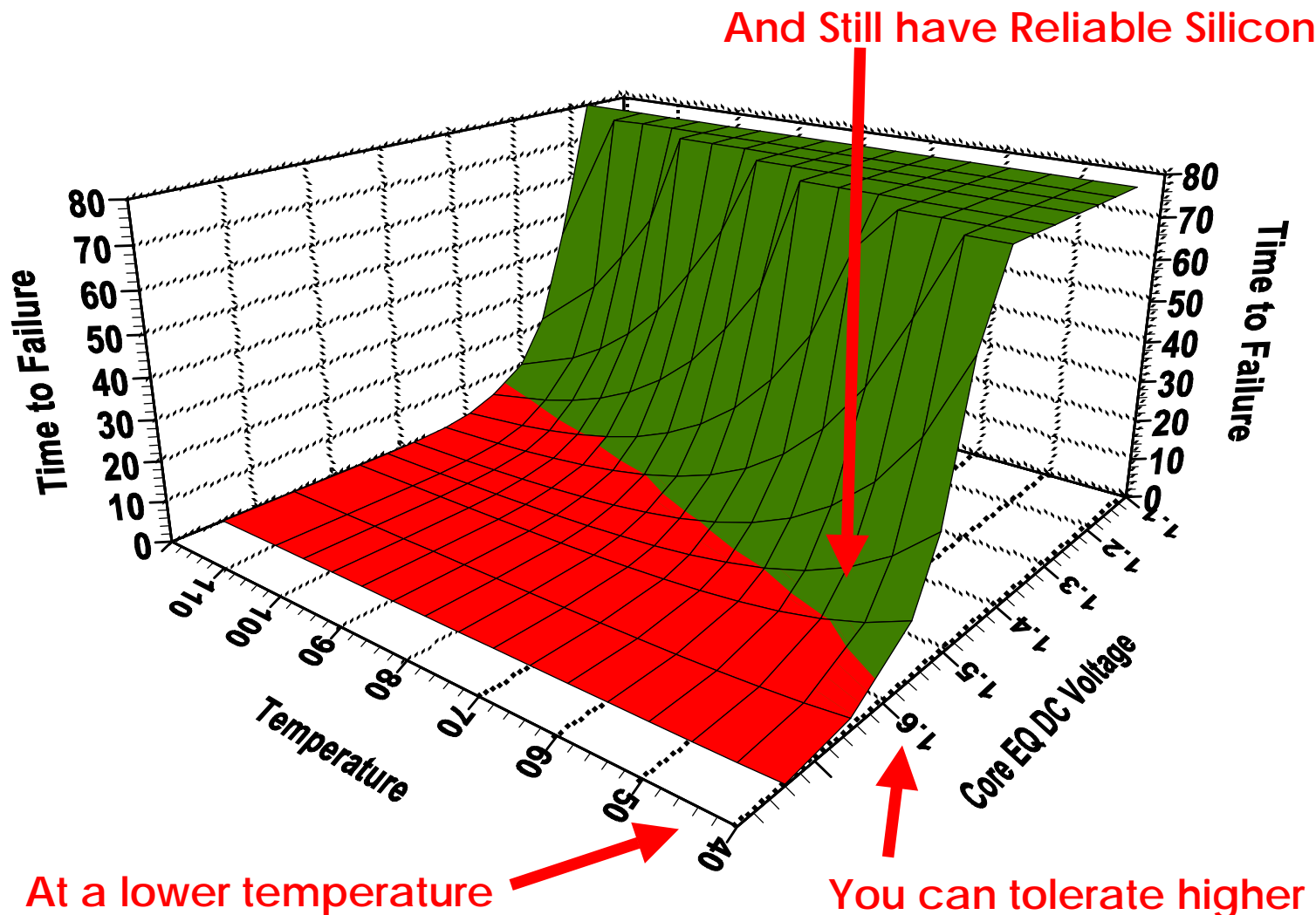
- It all comes to maintaining die temperature at or below a fixed value to
 - Ensure performance (typically Mhz), and
 - Reliability
- while dissipating power to a local ambient



Why maintain die temperature ?



Why maintain die temperature ?

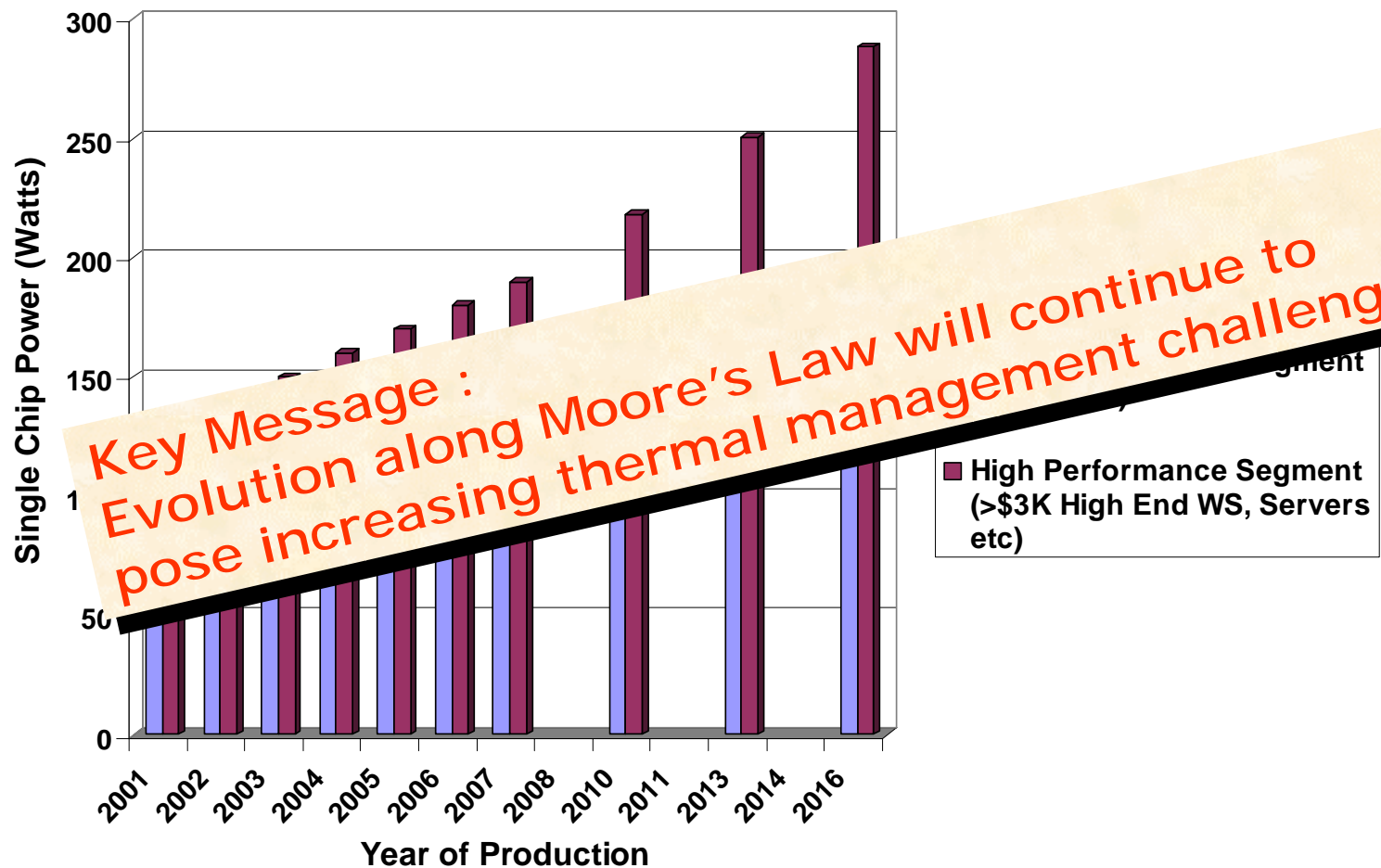


The Thermal Challenge

1. Power and Power Density Trends
2. System integration trends

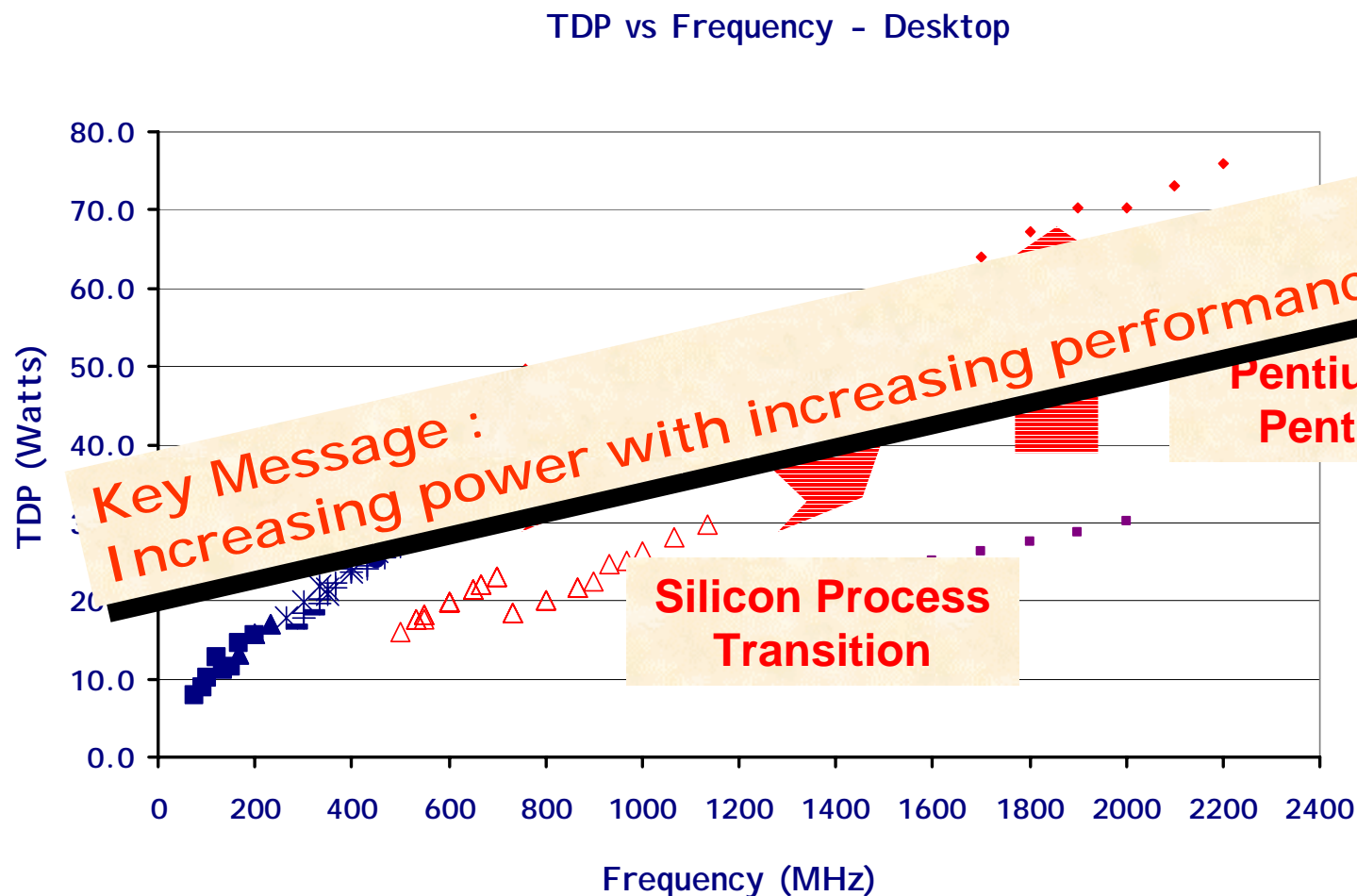
Increasing CPU Power ...

Industry trends

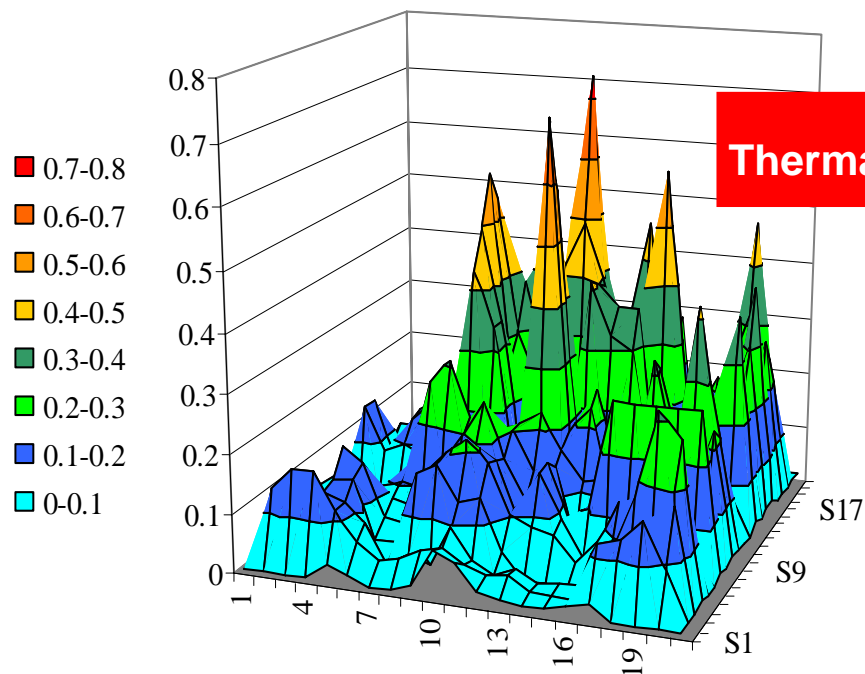


Increasing CPU Power ...

Intel trends

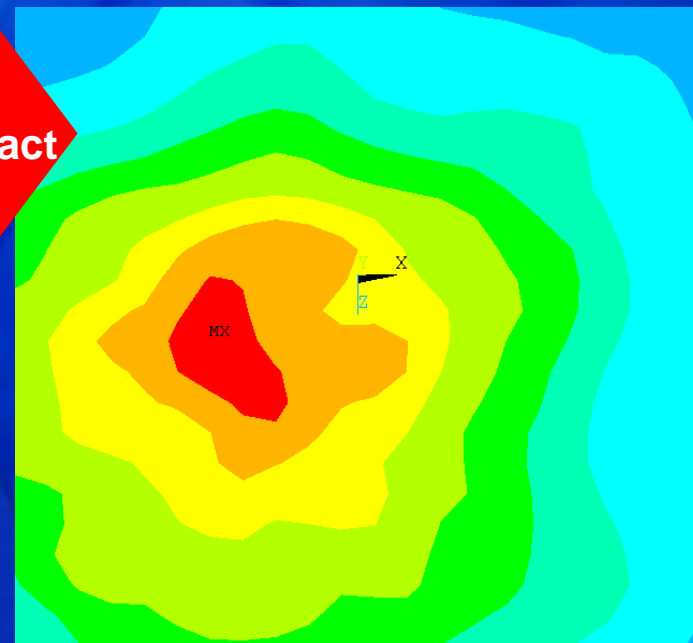


Increase in “Hot Spots”... Power distribution not uniform!



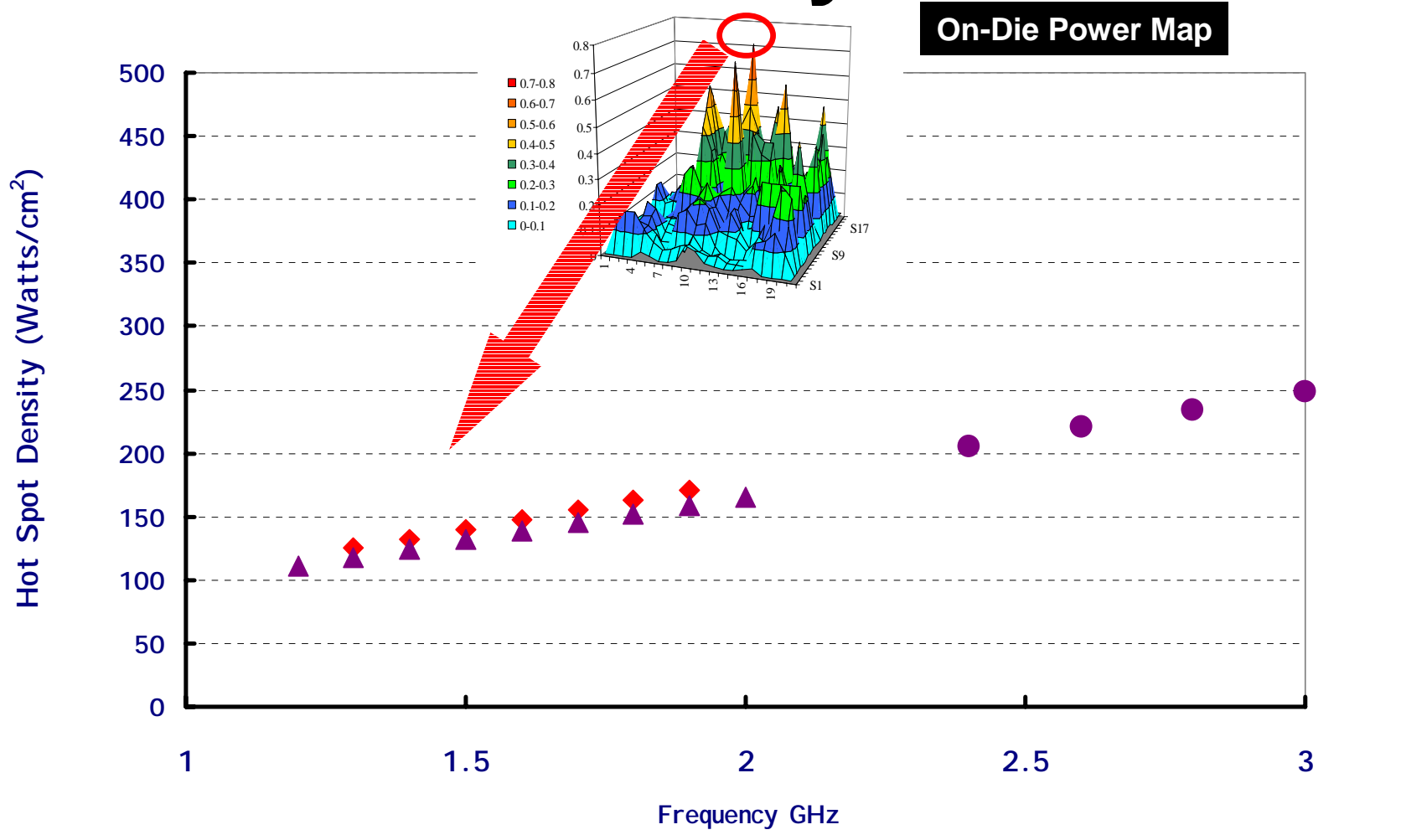
On-Die Power Map

Thermal Impact



On-Die Temperature Map

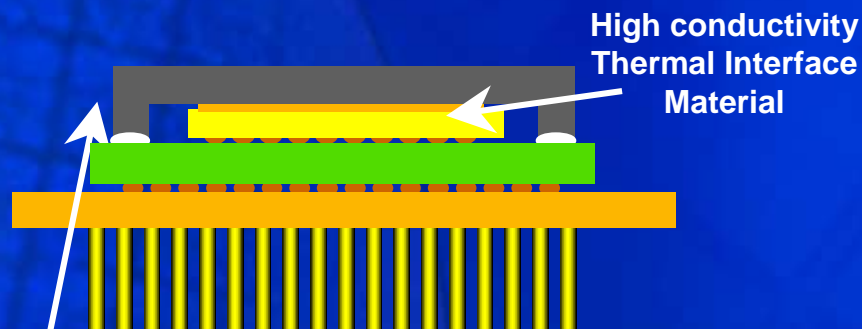
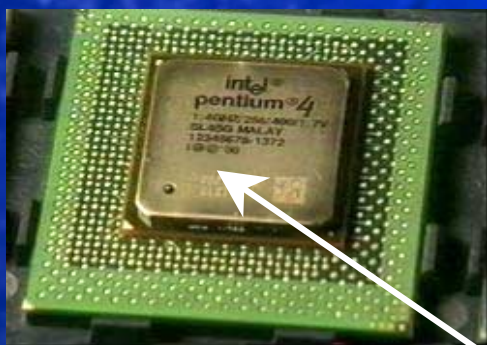
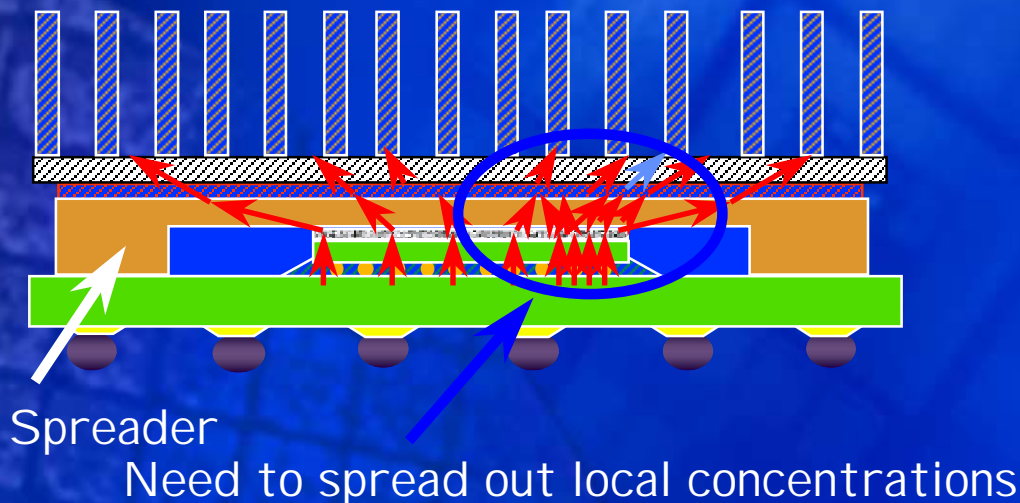
Increasing “Hot Spot” Power Density



Why are Hot Spots a Big Deal ?

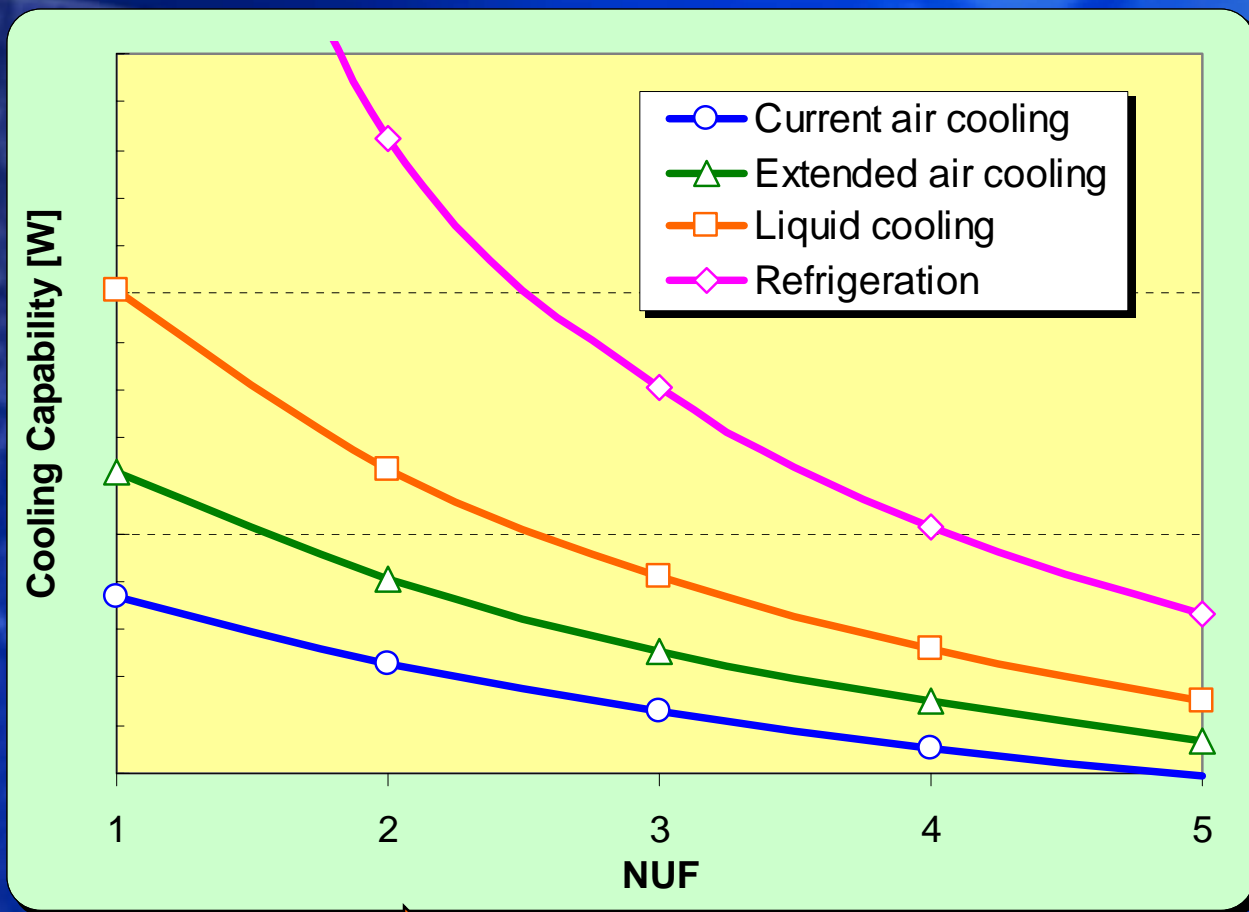
1. Adds complexity to Thermal Solutions

- ⇒ Drives designs to smooth out hot spots & duct heat to the ambient



Why are Hot Spots a Big Deal ?

2. Decreases cooling capability



Increasing Non-Uniformity

The Thermal Challenge

1. Power and Power Density Trends
2. System integration trends

Multiple Form Factors

Desktop Case Styles



Server Chassis Styles



Ultra-Dense
Rack-Mount



Rack-Mount



Clustered



Portable Tower



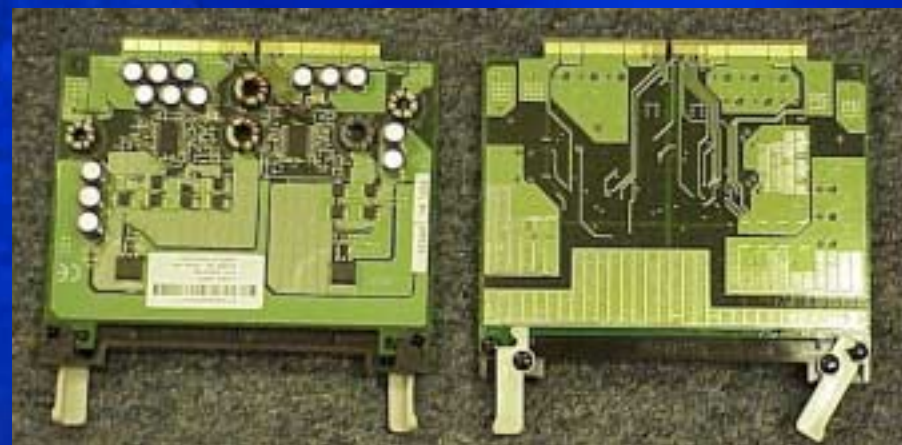
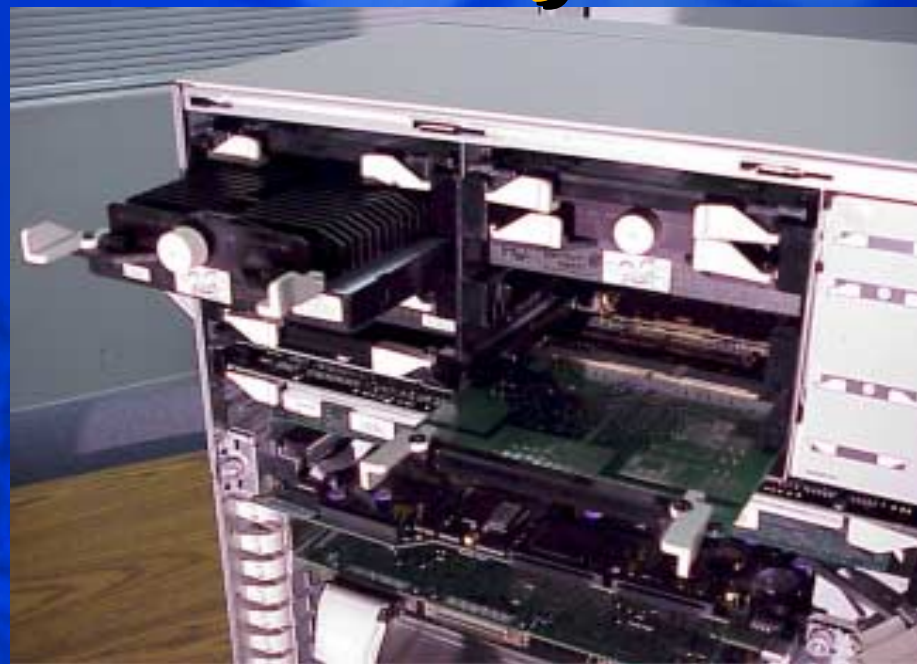
Tower



Large Tower

Impact : Ensuring Heatsink "Fit" is Challenging

Increased Integration & Component Density



Agenda

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Multi prong approach

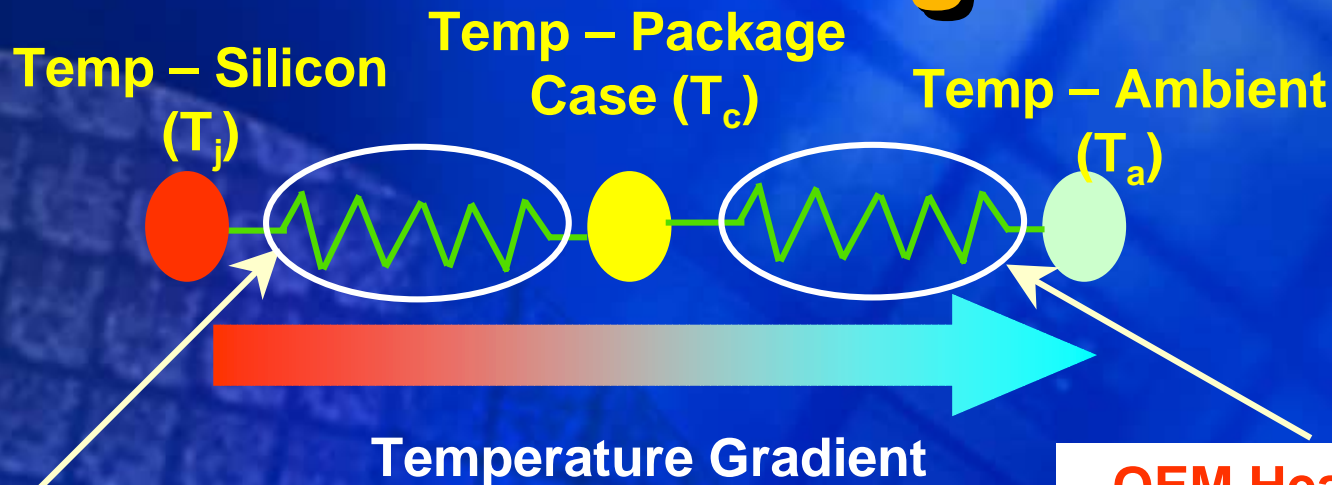
- **Manage the source**
 - More power efficient architecture
 - Slow the power increase trend

■ ● **Improve packaging**

■ ● **Develop and enable improved heat sink solutions at system level**

Total Package + System Solution Thermal Budget

22



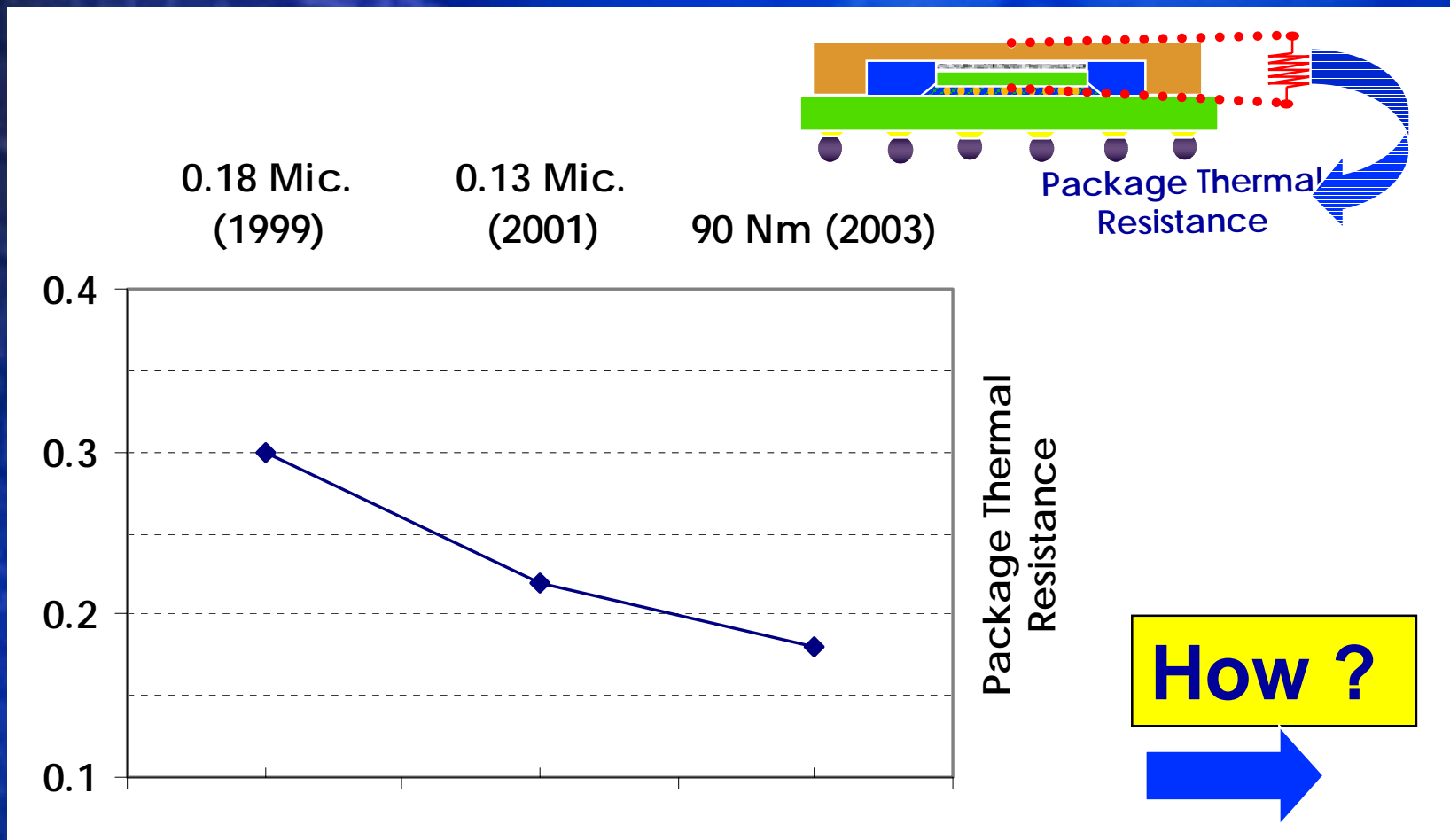
Packaging
Provide Solutions
for this interface
of the budget :
Smooth out Hot Spots

OEM Heat Sink
Provide Solutions
for this interface
of the budget

**Integrated Thermal Solutions in the
package reduce heat flux – easier to cool in
the system**

Consistent improvement in packaging

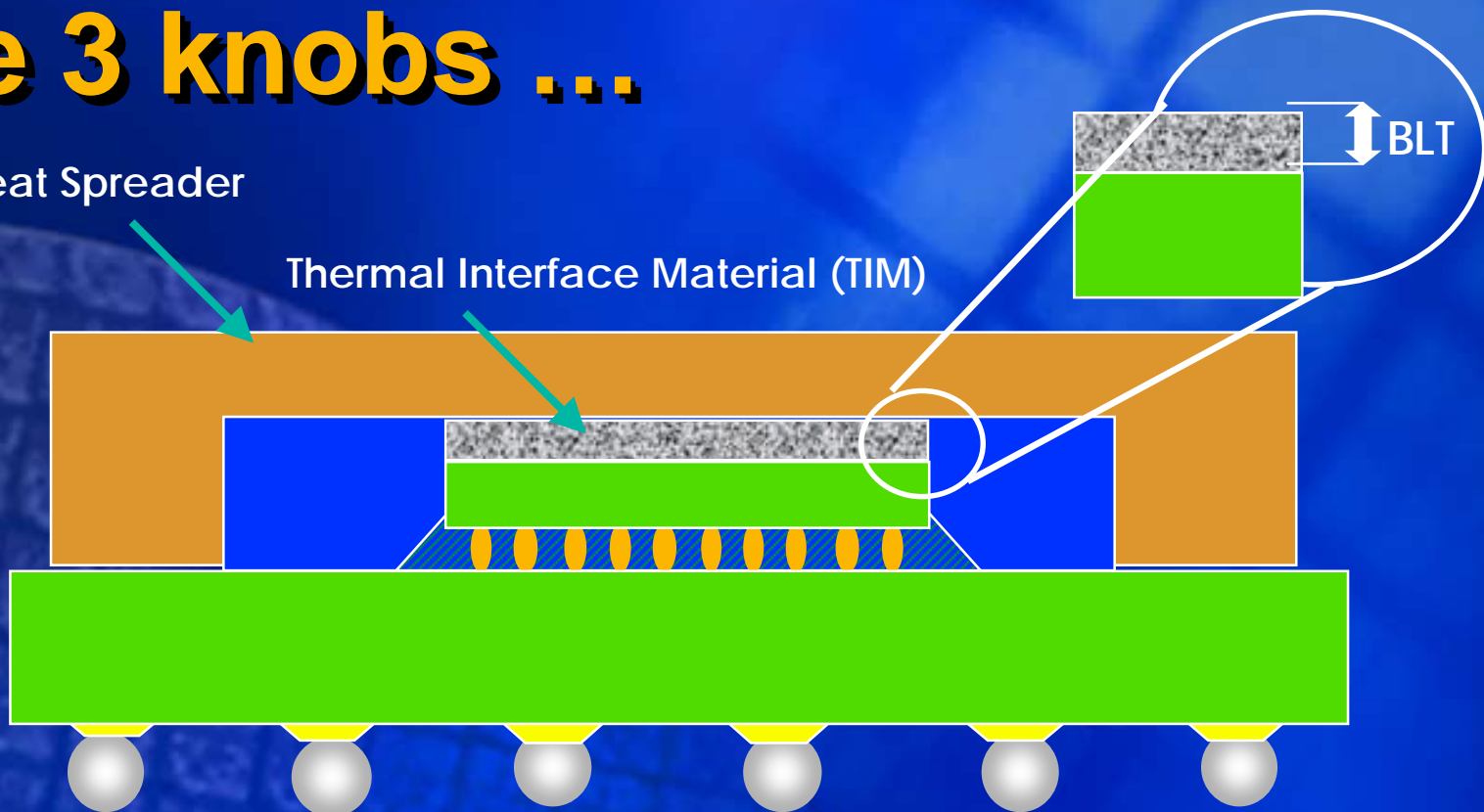
- ~ 22% thermal improvement per Silicon generation



The 3 knobs ...

Heat Spreader

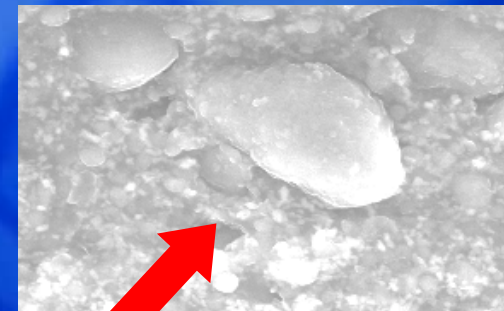
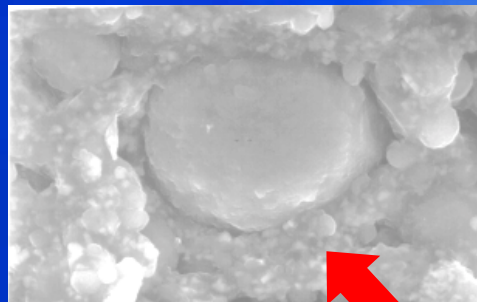
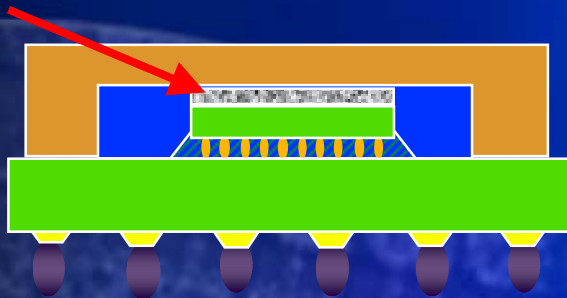
Thermal Interface Material (TIM)



- Improved TIMs : Better Thermal Conductivity, mechanical & chemical stability
- Tight Process Control : Controlled TIM Bond Line Thickness (BLT)
- Optimized Spreader design, material & technology

1. TIM Improvements

Thermal Interface Material (TIM)

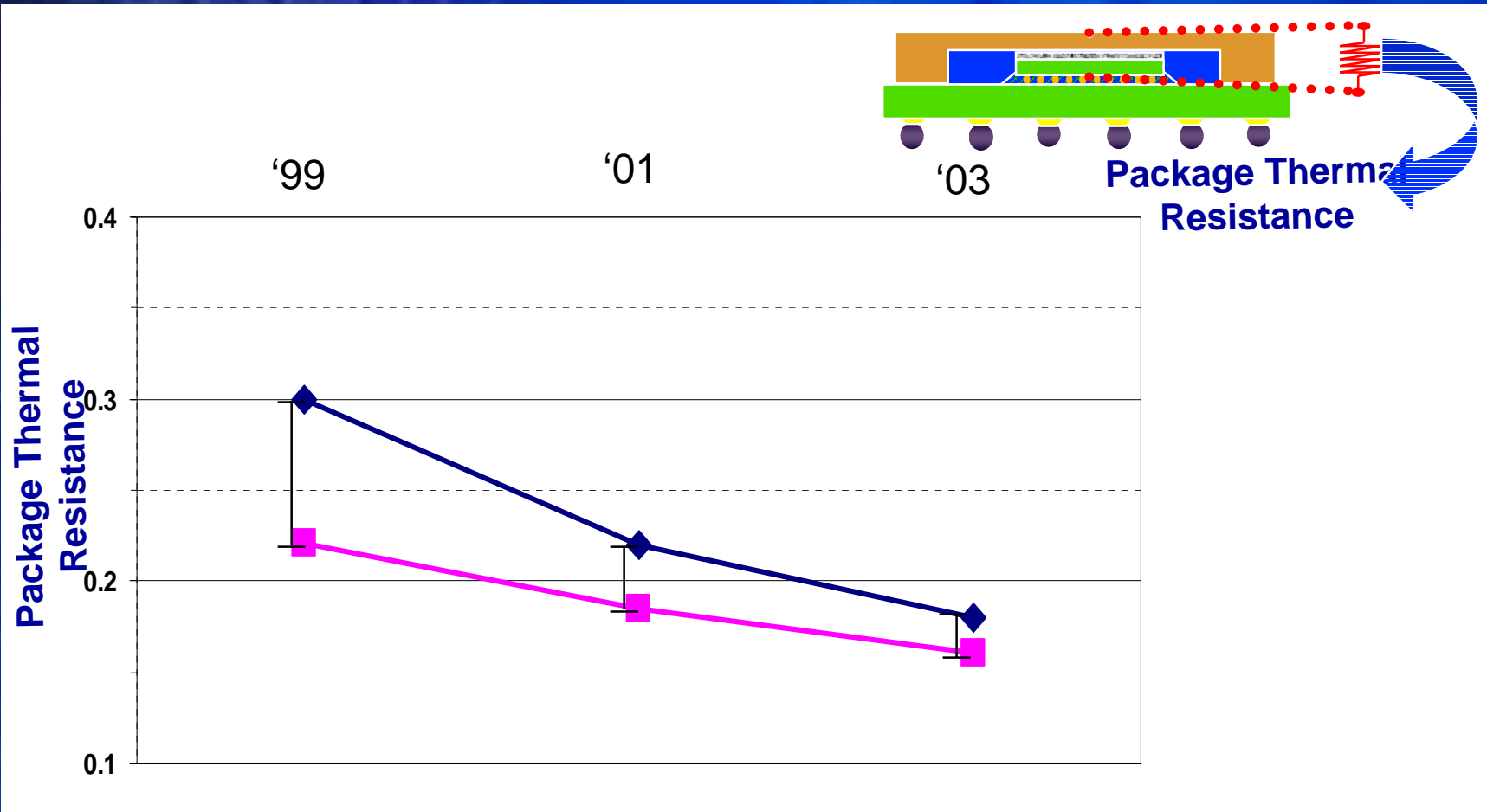


SEM Micrographs of TIMs w/ Regular & Irregular Fillers

- **TIM bulk thermal conductivity**
 - Heat conducts by percolation through fillers in the TIM
 - Filler size, size distribution, & shape carefully selected to optimize conductivity
- **Interfaces (Die/TIM & Heat Spreader/TIM) carefully tailored to maximize heat transfer**

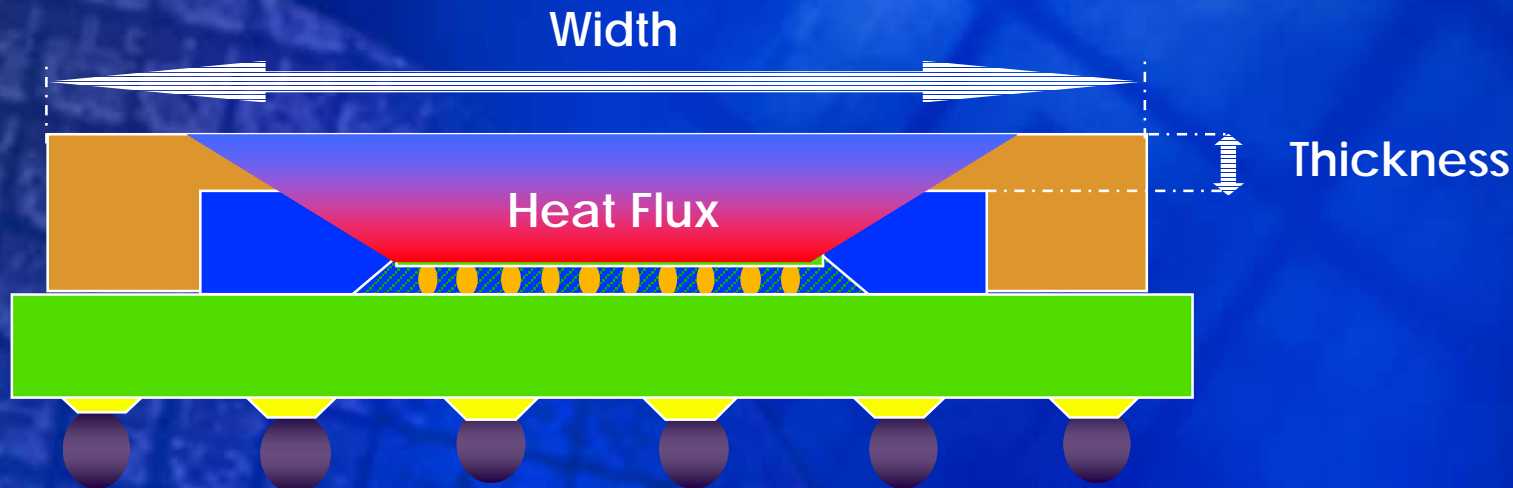
2. Process Control

- Sources of variability tracked and minimized

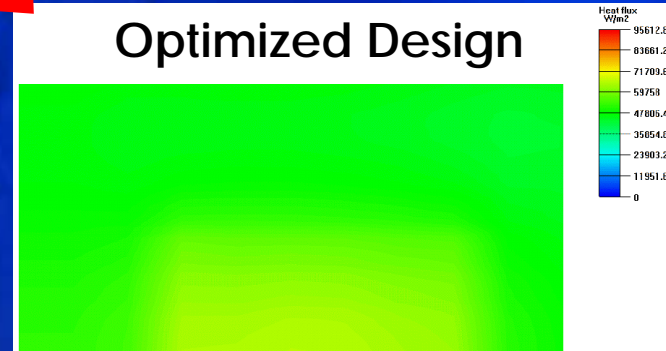
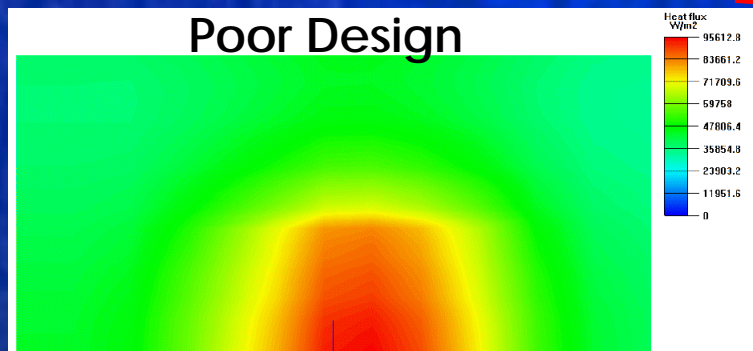


3. Spreader Designs

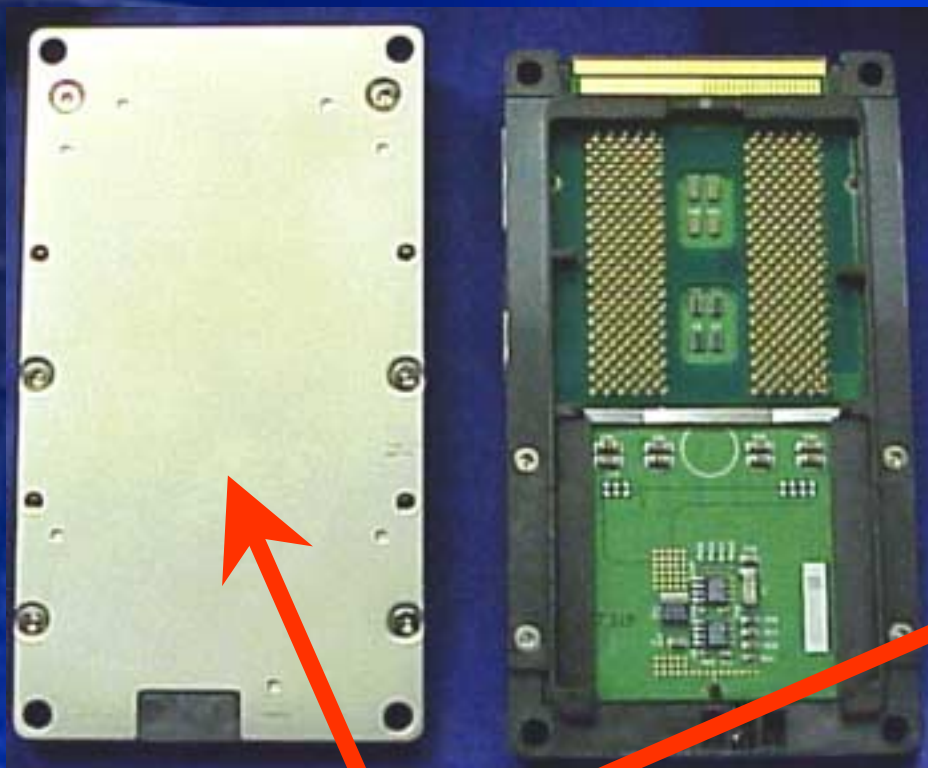
- Spreader material, thickness & width optimized to ensure top surface has a uniform heat flux



TOP VIEWS OF HEAT SPREADER



3. More complex spreader technologies



Integrated heat pipe
technology interfacing
directly to the
silicon



Example : Itanium[®]

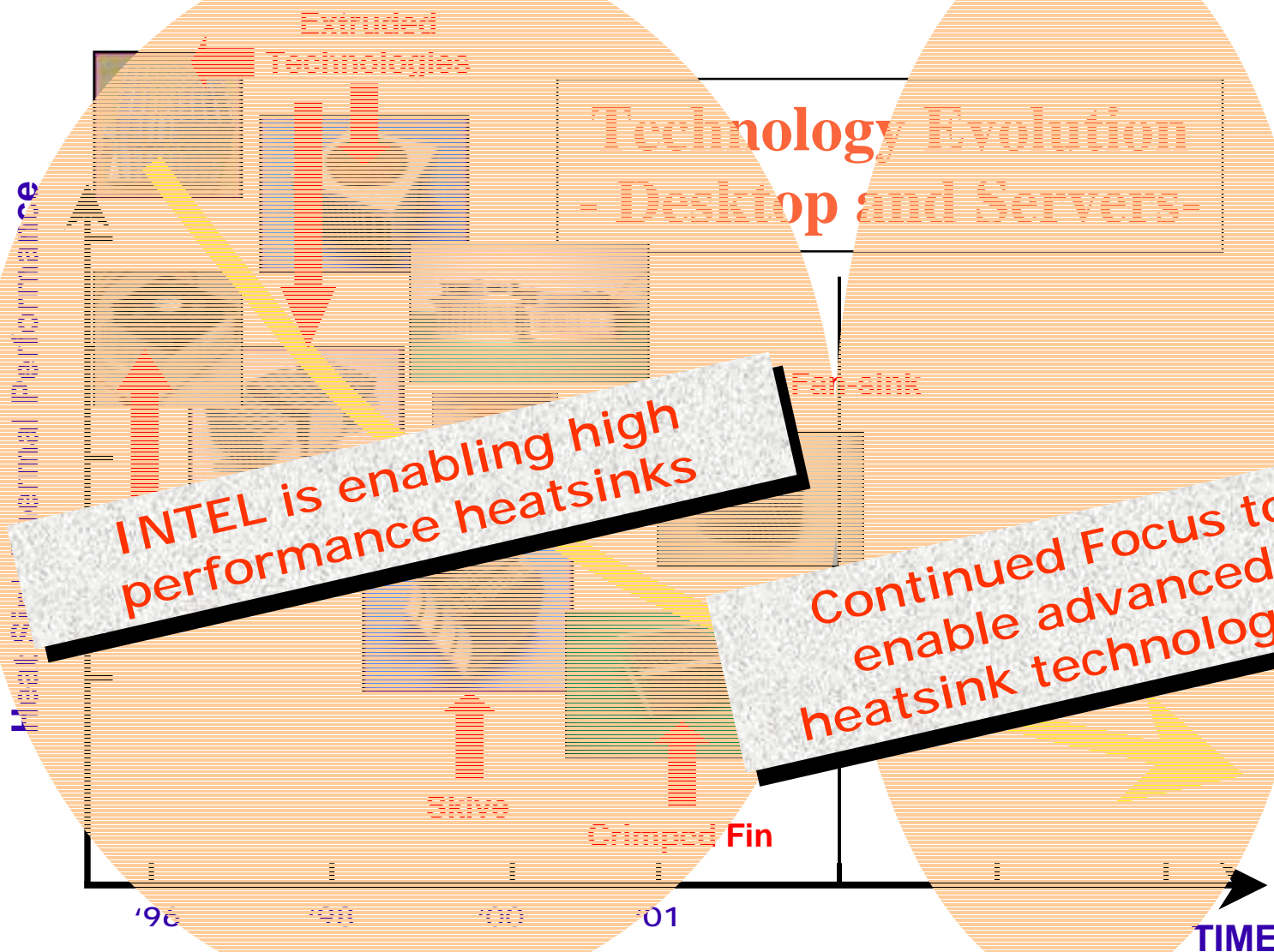
Multi prong approach

- **Manage the source**
 - More power efficient architecture
 - Slow the power increase trend

- **Improve packaging**

- ● **Develop and enable improved heat sink solutions at system level**

Desktop & Server OEMs



Laptop OEMs

Focus Area 1 : Improve
TIMs & Attach Methods

Focus Area 3 : Improve
Fans & Heat Exchangers

**Key Message : Multi-Focus Effort to improve all
aspects of cooling in Laptops**

TIM

Heat Pipe

Air Inlet

Air Exhaust

Focus Area 2 : Improve
Heat-pipe performance

Summary

- Thermal management complexity is a component and system level challenge
- Increasing power, power densities, shrinking system sizes and system integration trends are the key challenges
- Intel's approach is a proactive holistic research model – silicon architecture + packaging + heat sink solutions

Thank You !

For more information, please visit

**Silicon
Showcase**
Breaking Barriers
to Moore's Law

<http://www.intel.com/research/silicon/packaging.htm>

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